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E. Serebryakova / D. Kholodnyak / I. Vendik

Design of one octave 3-bit digital phase shifter using metamaterial transmission lines with negative dispersion

MICRO- AND NANOELECTRONICS

The conventional transmission line with the positive phase velocity can be referred to as the right-handed transmission line (RH TL). One can consider such a transmission line as a network formed by a combination of series inductors and parallel capacitors. The dual transmission line (the line with interchanged capacitors and inductors) has negative phase velocity and is referred to as the left-handed transmission line (LH TL) [1]. The dispersion characteristics of the RH TL and the LH TL are rather parallel within a wide frequency range providing almost constant phase difference. This gives a possibility to design broadband digital phase shifters based on switching between the RH TL and LH TL sections [2]. The operational principle of such a phase shifter is illustrated by Fig. 1. Two SPDT switches, which could be based on p-i-n diodes, are used to change the signal path.

A 3-bit digital phase shifter with the operating bandwidth of one octave (2-4 GHz) was designed by cascading 45º, 90º, and 180º phase shifters based on switchable RH TL and LH sections. An artificial lumped-element realization of the LH TL section has to be used since that transmission line with negative phase velocity does not exist in the nature. Meanwhile, the natural transmission line section can be used as RH TL. The coplanar realization of the 3-bit phase shifter is shown in Fig. 2. The phase shifter was implemented as a multilayer ceramic structure by means of the sandwich technology using screen printing technique [3].

The size of the phase shifter is 40×20×1.1 mm^3. Fig. 3 shows simulated amplitude and phase characteristics for all eight states of a 3-bit phase shifter. The predicted phase shift error in the operating bandwidth is ±2° for small values of the

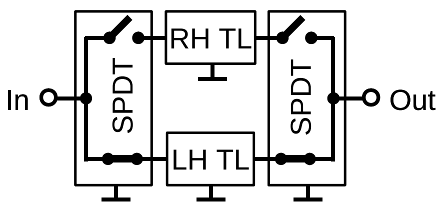

Fig. 1. Digital phase shifter based on switchable RHTL and LHTL sections.

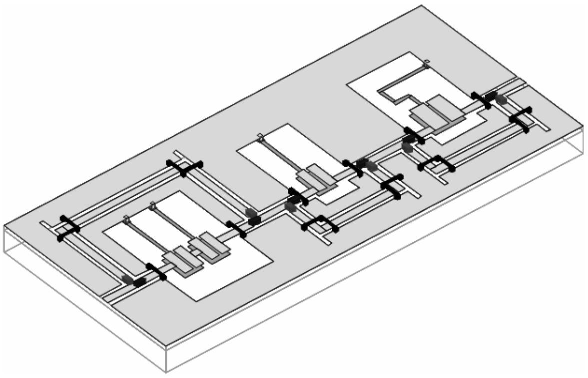

Fig. 2. Coplanar realization of the 3-bit digital phase shifter using the artificial quasi-lumped-element LH TLs and the natural RH TLs

phase shift and $\pm 8^\circ$ for the highest value of the phase shift. The return loss in the same bandwidth is no less then 15 dB. The insertion loss does not exceed 0.6 dB.

Experimental investigations of 180^o - bit revealed a good agreement between measured and simulated characteristics [4]. This confirmed the ability of the phase shifter designed to exhibit a high performance over one octave operational bandwidth.

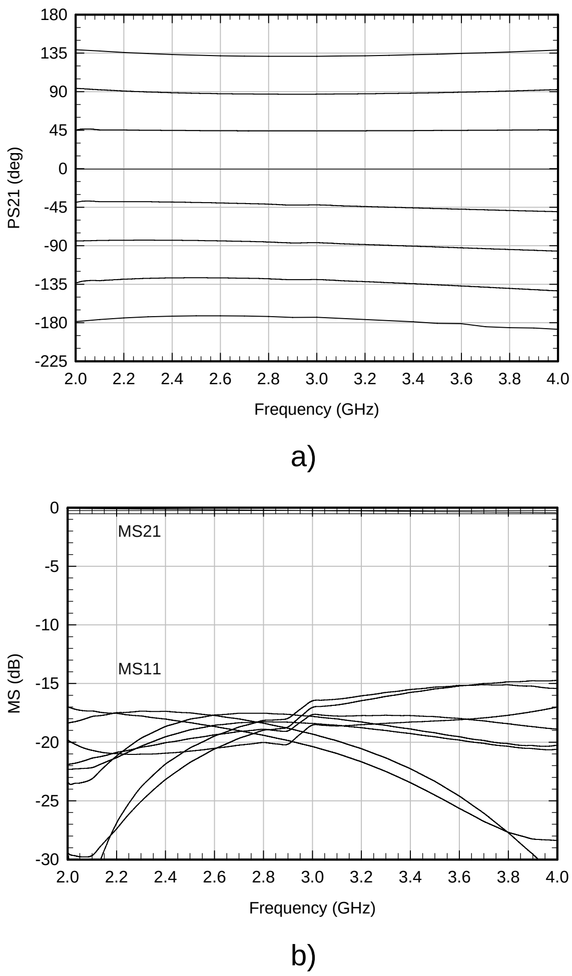

Fig. 3. Simulated amplitude and phase characteristics for all eight states of the 3-bit phase shifter designed.

References:

[1] C. Caloz and T. Itoh, Electromagnetic metamaterials: transmission line theory and microwave applications, Wiley, N.Y., 2006.

[2] O. G. Vendik, I. B. Vendik, D. V. Kholodnyak, S. P. Zubko, and E. V. Serebryakova, "Electronically controlled phase shifters based on right/left-handed transmission lines", Proc. of 35th European Microwave Conference, Paris, France, October, 2005, pp. 909-912.

[3] P. Kapitanova, A. Simine, D. Kholodnyak, and I. Vendik, "Application of Sandwich Multilayer Technology to MICs Design", Proc. of 35th European Microwave Conf., Paris, France, Oct. 2005, pp. 389-392

[4] I. B. Vendik, O. G. Vendik, D. V. Kholodnyak, E. V. Serebryakova, and P. V. Kapitanova, "Digital phase shifters based on right- and left-handed transmission lines", Proc. of European Microwave Association, 2006 (in print)

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